

Endovascular Management of Blunt Renal Artery Trauma

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ABSTRACT: **Background:** Renal artery injuries are rarely encountered in victims of blunt trauma. However, the rate of early diagnosis of such injuries is increasing due to increased awareness and the liberal use of contrast-enhanced CT. Sporadic case reports have shown the feasibility of endovascular management of blunt renal artery injury. However, no prospective trials or long-term follow-up studies have been reported.

Objectives: To present our experience with endovascular management of blunt renal artery injury, and review the literature.

Methods: We conducted a retrospective study of 18 months at a level 1 trauma center. Search of our electronic database and trauma registry identified three patients with renal artery injury from blunt trauma who were successfully treated endovascularly. Data recorded included the mechanism of injury, time from injury and admission to revascularization, type of endovascular therapy, clinical and imaging outcome, and complications.

Results: Mean time from injury to endovascular revascularization was 193 minutes and mean time from admission to revascularization 154 minutes. Stent-assisted angioplasty was used in two cases, while angioplasty alone was performed in a 4 year old boy. A good immediate angiographic result was achieved in all patients. At a mean follow-up of 13 months the treated renal artery was patent in all patients on duplex ultrasound. The mean percentage renal perfusion of the treated kidney at last follow-up was 36% on DTPA renal scan. No early or late complications were encountered.

Conclusions: Endovascular management for blunt renal artery dissection is safe and feasible if an early diagnosis is made. This approach may be expected to replace surgical revascularization in most cases.

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agement of blunt renal artery injury. We report three cases of patients treated via the endovascular approach at our facility and review the current medical literature on the subject.

PATIENTS

PATIENT 1

A 24 year old motorcyclist was admitted to the trauma unit 37 minutes after being involved in a truck collision. Upon admission he was fully conscious and hemodynamically stable. He complained of abdominal, left hand and right leg pain. Examination revealed left distal radius, phalanges, and right tibial plateau fractures together with a deep laceration on the right calf. Chest X-ray was within normal limits. CT revealed a grade III right liver lobe laceration as well as a right renal arterial irregularity together with reduced heterogenous parenchymal enhancement of the right kidney [Figure 1A]. Visceral angiography revealed severe circumferential narrowing of the middle portion of the right renal artery together with a filling defect, most probably caused by a circular intimal laceration [Figure 1B]. Stent-assisted angioplasty was performed with a 7 x 18 mm Genesis stent (Cordis, Warren, NJ, USA) with immediate restoration of normal arterial flow [Figure 1C]. Time from admission to revascularization was 171 minutes.

The patient was transferred to the intensive care unit. Anticoagulant therapy using low molecular weight heparin and antiplatelet therapy using salicylic acid were initiated. Closed reduction of the radial and phalangeal fractures, and open reduction and internal fixation of the tibial plateau fracture were subsequently performed. During his hospital stay the patient was normotensive and had a satisfactory urinary output with stable hemoglobin level and renal function tests. Prior to discharge, a renal DTPA uptake and secretion scan demonstrated a relative function of 41% and 59% of the right and left kidneys, respectively.

A follow-up renal DTPA scan performed 23 months after the injury revealed an even uptake in both kidneys and a relative uptake of 49% on the affected side. Blood pressure and blood creatinine level were within normal limits 22 months after the injury.

DTPA = diethylene triamine pentaacetic acid

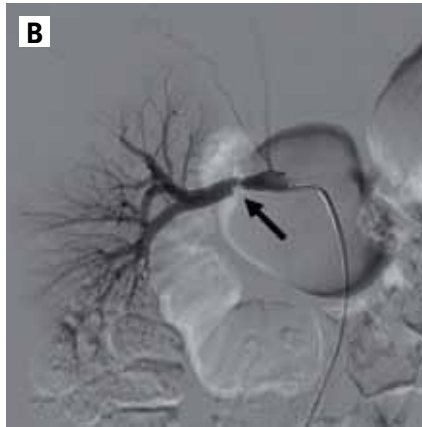
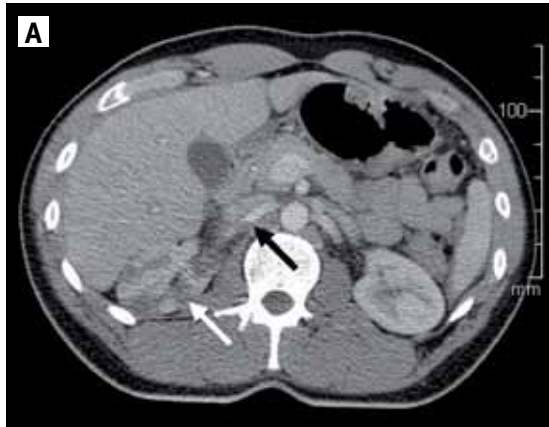
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Renal artery injuries are rarely encountered in victims of blunt trauma. However, the rate of early diagnosis of such injuries is rising due to increased awareness and the liberal use of contrast-enhanced computed tomography. Sporadic case reports have shown the feasibility of endovascular man-

Figure 1. [A] Contrast-enhanced abdominal CT scan showing right renal artery irregularity (black arrow) and reduced heterogenous parenchymal enhancement of the right kidney (white arrow)

[B] Visceral angiography with selective injection to the right renal artery showing arterial narrowing and irregularity (arrow)

[C] Right renal arteriography after stent (arrow) placement showing excellent antegrade flow



PATIENT 2

A 4.5 year old boy was admitted to the trauma unit one hour after sustaining injury to his right abdomen from a military vehicle. Upon arrival at the trauma unit he was fully conscious and hemodynamically stable. He had lacerations on the right cheek and right abdomen with minimal right abdominal tenderness. Chest and pelvic X-rays were normal. FAST (focused abdominal sonography in trauma) was positive for fluid in the pelvis.

CT scan demonstrated a grade IV liver laceration, a small amount of fluid in the pelvis, and right renal artery filling defect with flow cutoff and no enhancement or excretion from the right kidney [Figure 2A]. Celiac arteriography showed no signs of active bleeding. Aortography revealed minimal perfusion of the right kidney with no excretion, and selective

arteriography demonstrated an occlusion approximately 2 cm from the ostium [Figure 2B].

After carefully passing a guide-wire distal to the occlusion, graded renal artery angioplasty to a maximal diameter of 3.5 mm was performed. A good angiographic result was obtained with restoration of flow but patchy parenchymal enhancement, without evidence of vessel rupture [Figure 2C]. Altogether, the patient received 25 ml of contrast material. Time from admission to revascularization was 110 minutes.

The patient was transferred to the pediatric ICU. Anti-coagulant therapy with heparin was initiated and titrated to a partial thromboplastin time of > 60 seconds. He remained

ICU = intensive care unit

Figure 2. [A] Contrast-enhanced abdominal CT scan showing right renal artery occlusion (black arrow), no enhancement of the right kidney (white arrow) and four degree liver laceration (asterisk)

[B] Visceral right renal artery arteriography showing a near occluding dissection (arrow) with minimal perfusion of the right kidney and no excretion. Note the outline of the left pelviciceal system

[C] Angiographic result after balloon angioplasty showing restoration of flow but patchy renal parenchymal enhancement

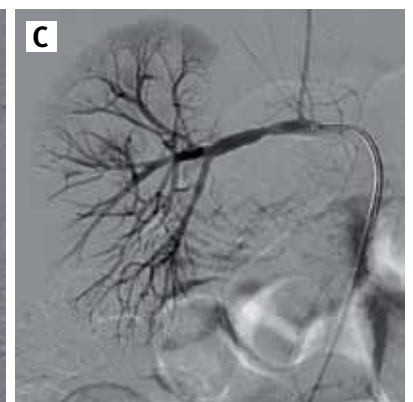


Figure 3. [A] Contrast-enhanced abdominal CT scan showing right renal artery irregularity (black arrow) and loss of enhancement of the posterior part and upper pole of the right kidney (white arrow)



[B] Right renal arteriography showing two arterial branches with flow cutoff in one of them (arrow) and loss of enhancement of the kidney's upper pole



[C] Right renal arteriography after stent placement showing intact flow through both arterial branches and uniform renal enhancement



hemodynamically stable, was normotensive and had normal creatinine levels.

Ultrasound with duplex of the kidneys was performed on the second day of hospitalization, which showed normal flow in the right renal artery. The patient was discharged home 10 days after admission. Subsequent ultrasound and duplex were normal with a resistive index of 63–73% on both kidneys one month after the injury. A renal DTPA scan at this time showed an uptake of 11% on the affected side. A subsequent scan performed 14 months after the injury showed an improvement to a relative uptake of 19% on the affected side. At the time of writing, the patient is developing normally and has a normal creatinine level and blood pressure.

PATIENT 3

A 19 year old male who was injured in a motor vehicle accident despite wearing a seat belt was admitted to the trauma unit 40 minutes after the accident. Upon admission he was fully conscious, hemodynamically stable and had no signs of respiratory distress. Physical examination revealed a broken nose and superficial bruises all over his body. Chest and pelvic X-rays as well as FAST were normal. CT scan demonstrated partial enhancement of the right kidney and right renal artery irregularity [Figure 3A].

Visceral angiography revealed a double right renal artery with cut-off of the flow in the main renal artery branch with loss of enhancement of the upper and lower poles of the right kidney [Figure 3B]. Since angioplasty with a 3 mm balloon achieved a suboptimal result, a Palmaz® Blue™ 5 x 15 mm stent (Cordis, Warren, NJ, USA) was inserted into the artery

with restoration of blood flow through the occluded branch achieving near total parenchymal enhancement [Figure 3C]. Time from admission to revascularization was 180 minutes.

The patient was transferred to the ICU. Anticoagulant therapy with LMWH and antiplatelet therapy with salicylic acid was initiated. During his hospitalization the patient was normotensive with normal kidney function tests. Prior to discharge, a renal DTPA scan was performed and showed a slightly decreased uptake at the upper pole with a relative function of 32% vs. 68% of the right and left kidneys, respectively.

Two months later a repeat renal scan showed some improvement of the right renal function to 40%. At clinic follow-up 4 months after the injury, the patient felt well and his blood pressure and creatinine level were normal. Follow-up ultrasound and duplex was normal with a resistive index of 65–72% on both kidneys.

DISCUSSION

Blunt renal artery injury is a rare condition in trauma patients. Fewer than a thousand cases were reported in the literature since first described by Von Recklinghausen in 1861 [1]. The incidence of renal artery injury from blunt trauma ranges between 0.05%, as reported by Demetriades' group in the National Trauma Data Bank [3], and 0.08% as reported by Bruce et al. [4].

Although the left kidney is reported to be slightly more prone to injury, all three of our patients had injuries to the right kidney. The literature suggests that the relative rate of injury is 1.4–2:1 when comparing left to right sides. Possible explanations for this include the following: firstly, the right renal artery is shielded

FAST = focused abdominal sonography in trauma

LMWH = low molecular weight heparin

and stabilized by the inferior vena cava and duodenum while the right kidney is stabilized in place by the liver and duodenum. In contrast, the left renal artery is shorter and more acutely angled than the right and is thus more prone to stretch injury [5,6].

Children may be particularly susceptible to renal artery injury in blunt trauma. This is attributed to the relatively larger kidneys in the pediatric population, their higher mobility, and a relative lack of surrounding protective tissues [7].

Mechanisms for BRAI involve sudden acceleration-deceleration forces that cause a stretch injury to the vessel wall, or direct impact with compression of the renal vessel against the vertebral column. The kidneys are fixed in place only by means of the vascular pedicle and the ureter, thus injuries usually occur at these points.

Renovascular injuries usually occur about 2 cm from the origin of the main renal artery but may involve branch renal vessels, as was seen in one patient in this series [8]. Injuries have been classified as vessel avulsion, laceration or dissection. The former two subtypes necessitate immediate surgery due to hemorrhage. Nephrectomy or early vascular reconstruction is possible. Traumatic dissection of the renal artery may lead to stenosis or occlusion of the renal artery due to the presence of an intimal tear with secondary thrombus formation [9].

The kidneys are extremely vulnerable to warm ischemia. The impact of the ischemia time is even greater when complete occlusion of the renal artery occurs as there is minimal collateral renal blood flow beyond the point of occlusion. Thus, the most critical factor in preserving renal function is the reestablishment of blood flow as early as possible. Spirnak and Resnick [10] defined the optimal time frame for revascularization as 6–12 hours from injury. However, ischemic changes start to appear around 60–120 minutes after injury, thus we tend to believe that the optimal time frame is likely to be much shorter, between 3 and 4 hours, as stated by Cass [5] and Flye et al. [11]. In our series, the mean time from injury to endovascular revascularization was 193 minutes (range 150–220 minutes), and the mean time from admission to revascularization was 154 minutes (range 110–180 minutes).

Patients suffering renal artery avulsion or laceration may present with hemorrhagic shock. However, intimal injuries or small lacerations are typically asymptomatic. A high index of suspicion together with high quality imaging is necessary for early detection and treatment of such injuries. Hematuria is present in most cases of renal trauma; however, its presence and severity do not correlate with the severity of injury. Hematuria may be absent in up to a third of patients sustaining injury to the renal vessels [5,9,12]. None of the patients in our series had macrohematuria.

Patients presenting after rapid deceleration or direct injury, or with tenderness on the flank or lateral abdomen, or with hematuria, are suspected of having BRAI. In the past such

patients underwent intravenous urogram, but this diagnostic test has a 30% false negative rate. Over the last 20 years contrast-enhanced CT has been considered the imaging modality of choice in renal trauma patients. Furthermore, CT has a major role in the diagnosis of associated injuries in stable trauma patients. Intravenous urogram, however, may still have a role in the diagnosis of renal injuries in unstable patients in the operating room [13].

The following CT findings are suggestive of renal artery injuries:

- An abnormal contrast-enhancement pattern relative to the contralateral kidney. This may range from irregular linear hypodensities to delayed or diminished enhancement of the affected kidney. This “asymmetric nephrogram” is more prominent as the degree of injury increases, reflecting the severity of renal parenchymal ischemia [14] [Figures 1A, 2A, 3A]
- Non-opacification of the pelvi-calyceal system, reflecting an ischemic non-excreting renal parenchyma [Figure 2B]
- The “cortical rim sign,” indicating non-enhancing renal parenchyma except for the peripheral outer portion of the cortex, which may represent perfusion from capsular collateral blood flow [5] [Figure 2A]
- Direct visualization of renal artery irregularity, filling defect, contrast media extravasation or complete vessel occlusion [Figures 1A, 2A, 3A].

Selective renal angiography remains the gold standard for diagnosing renal artery injury, since it has the highest sensitivity and specificity. However, as a diagnostic tool it is reserved only for selected patients with a high level of suspicion for BRAI and a non-conclusive CT scan. In our current practice catheter angiography provides a platform for the endovascular treatment of BRAI in selected patients.

The management of BRAI remains controversial and has been the center of much debate in the last 30 years. In more than two-thirds of patients there may be associated intraabdominal and extraabdominal injuries. Those injuries not only contribute to higher morbidity and mortality but also influence the timing and method of treating renal artery injuries [3,9]. High grade renal injuries with persistent hemodynamic instability are very rare. The treatment options for such cases are emergent laparotomy together with early nephrectomy, partial nephrectomy, arterial repair or renal autotransplantation.

Most patients, however, sustain less severe renal artery injuries. Treatment of these injuries has evolved over time. In 1971 Rohl [2] described the successful revascularization of a thrombosed renal artery in a 25 year old man. Historically, most patients sustaining renal artery trauma underwent surgical exploration with renal artery reconstruction or nephrectomy. The rationale for nephrectomy in avulsion or laceration of the renal artery, when reconstruction is not feasible, is clear. Nephrectomy was also performed semi-electively in order

BRAI = blunt renal artery injury

Table 1. Summary of the case reports of patients treated endovascularly for BRAI

Case	Age (yr)	Dx	Injury type	% RA stenosis	Time to reperfusion (hr)	Revascularization method	AC	HTN	RF
1	28	An	Dissection	75	> 24	Stent	A	NA	NA
2	23	CT	Decreased perfusion, no excretion	90	> 12	Stent	H, C	NA	45%
3	37	An	Dissection	75	NA	Stent	NA	NA	NA
4	25	CT	Reduced enhancement	95	NA	Stent	NA	No	43%
5	40	CT	Reduced enhancement	NA	NA	Stent	NA	No	42%
6	22	CT	Reduced enhancement	< 50	NA	Stent	None	NA	42%
7	21	An	Dissection	> 90	Next day	Stent	H, A	No	47%
8	40	CT	Complete RA obstruction	100	3	Stent	NA	Yes	14%
9	20	CT	Kidney laceration, delayed perfusion, no excretion	Severe dissection	9	Stent	H,A	No	40%
10	18	CT	Thrombosis	100	NA	Thrombolysis, stent	H,A	NA	NA
11	2	CT	Lack of enhancement	100	12	Stent	C	Yes	NA
12	17	CT	Lack of enhancement	90	18	Stent	NA	No	40%
13	43	CT	No perfusion	100	NA	Stent	None	NA	5% at 1 month
14	23	An	RA laceration	NA	NA	Stent	A	No	NA

RA = renal artery, Dx = diagnostic method, An = angiography, AC = anticoagulation, H = heparin, C = coumadin, A = aspirin, NA = not available, HTN = hypertension, RF = follow-up renal function on DTPA scan

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to prevent infection of the necrotic tissue and to prevent the development of renovascular hypertension.

Successful revascularization with restoration of normal kidney function was achieved in less than a quarter of the patients reported in the literature [4,15]. The low success rate for surgical revascularization combined with the trend for non-operative management of patients with blunt abdominal trauma has swung the pendulum towards a non-surgical approach for blunt renal artery trauma patients.

Renovascular hypertension remains a major concern with the conservative approach. Rates of hypertension in blunt renal artery patients range from 3% to 30% in different series [4,16-19]. The hypertension is mediated via renin hypersecretion

from the affected kidney and may normalize spontaneously, be controlled medically, or progress to severe hypertension that necessitates delayed nephrectomy [20].

First described by Whigham and co-authors in 1995 [21], angiographic revascularization has emerged as a promising additional therapeutic approach. In the last few years, growing experience and improved techniques with elective renal artery angioplasty and stenting for atherosclerotic disease and fibromuscular dysplasia have widened the application of this technique in the acute setting of trauma.

Review of the English-language literature revealed a total of 14 patients with BRAI treated via the endovascular approach [Table 1]. The mean age of the patients was 25 years (range

2–43) and half were male. The distribution of injury side was equal. Diagnosis was made in most cases using CT scan. In three cases the diagnosis was made via angiography. In most cases the injury caused significant renal artery flow restriction. Time to revascularization was not given in 8 of the 14 cases and ranged between 3 and 24 hours in the remaining six. Stent placement was performed in all cases. In one case report, catheter-directed thrombolysis preceded the stent insertion. After the procedure, treatment with anticoagulation or antiplatelet therapy was reported in half the cases. Long-term follow-up was not reported in 6 of the 14 patients. In the remainder, the follow-up ranged between 2 weeks and 4 years. Two patients developed renovascular hypertension, necessitating delayed nephrectomy in one patient. Renal function using DTPA scan was markedly reduced in two patients who suffered from complete renal artery occlusion.

In the National Trauma Data Bank study, only 8 patients (1.5%) with isolated BRAI were treated by means of angiographic stenting; no follow-up was reported for those patients [3].

At our level 1 trauma center, the early angiographic approach has become the preferred treatment approach in hemodynamically stable patients with dissection of the renal artery due to blunt trauma [22]. The liberal use of CT scan in trauma patients at our center, the high index of suspicion for BRAI, and the ability to perform therapeutic angiography swiftly, are reflected in the three patients treated angiographically over 18 months. We have found this approach to be safe and effective for treating such injuries. A good immediate angiographic result was achieved in all three patients, with re-establishment of blood flow to the affected kidney. No complications occurred during the procedures. We advocate the use of DTPA as a follow-up tool for kidney function assessment. Kidney function of the affected side was proven to be fairly preserved in all three patients with a mean relative activity of ~36%. After BRAI, once irreversible ischemic change has occurred it is unlikely that restoration of arterial patency will be translated to preservation of nephron function. Therefore, it is logical to assume that earlier revascularization would further improve long-term renal function. Every effort should be made to achieve this goal provided it is not at the expense of other life-saving procedures that should take priority. Delayed diagnosis of BRAI, when irreversible ischemic damage occurred, does not necessitate angiographic restoration of arterial blood flow. Those patients could be managed conservatively with close follow-up for hypertension development. In our three patients, no late complications occurred and no renovascular hypertension was detected.

In conclusion, endovascular management for renal artery injuries in blunt trauma patients appears to be safe and feasible. It is expected to replace surgical revascularization in most cases of renal artery dissection due to blunt trauma. A high index of suspicion for BRAI, swift accurate imaging diagnosis, and “as early as diagnosed” revascularization are required for achieving

renal function preservation. Long-term follow-up is required to identify the development of renovascular hypertension. Long-term post-procedure antiplatelet prophylaxis of late stent occlusion seems to be reasonable, but no guidelines are yet available.

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